

Speed 5G mmW Ant. Module Design

Speed Wireless Technology
2019.04.01



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SPEED

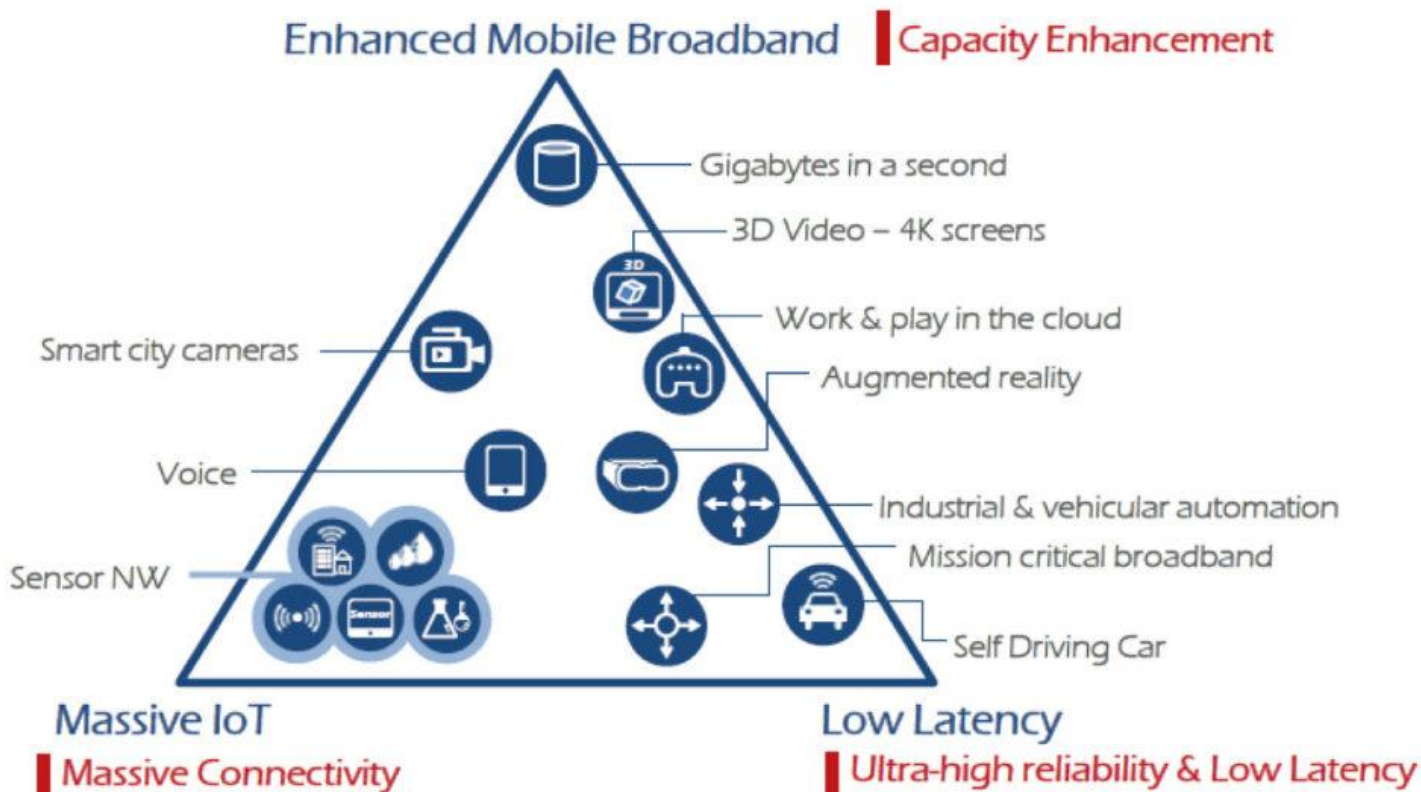
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Electronic Design Innovation Conference
电子设计创新大会

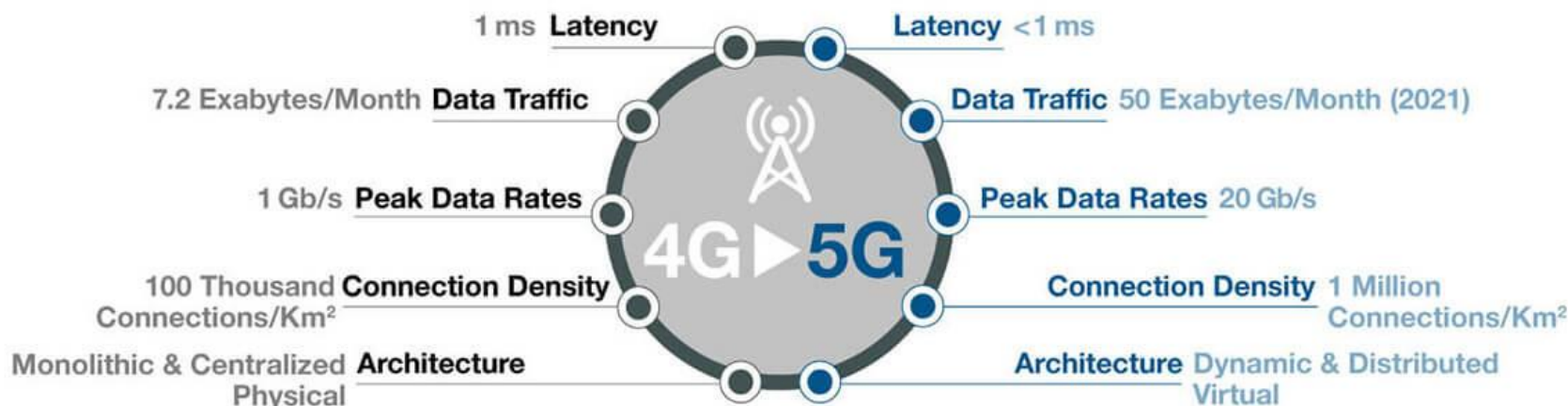
April 1-3, 2019
China National Convention Center
Beijing, China

- ***5G Intro. Overview***
- *mmW T/Rx RFIC Design*
- *mmW Ant. Module Design*
- *Terminal mmW Ant. Design*

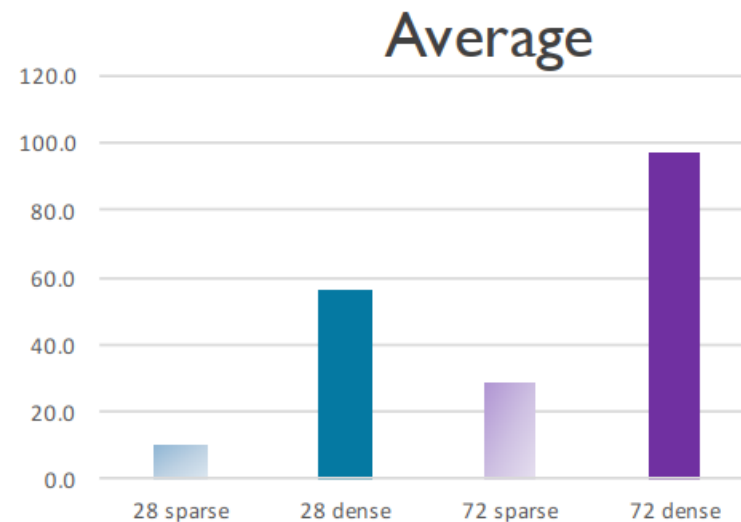
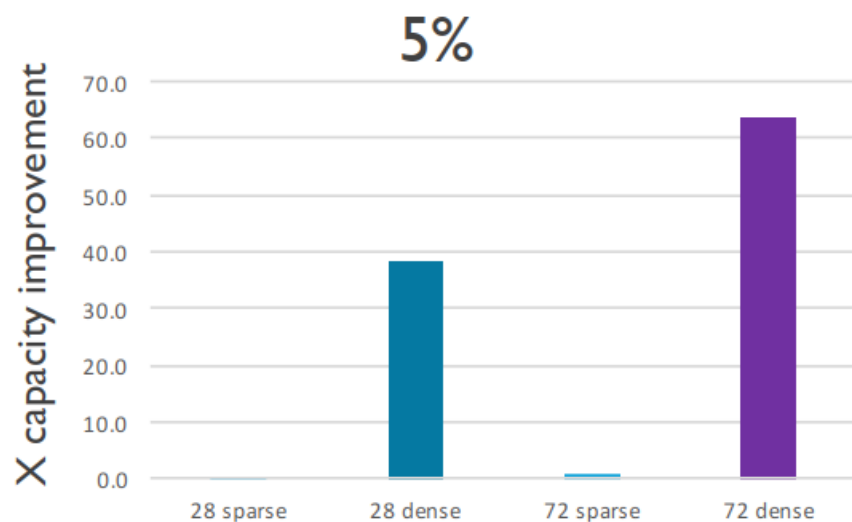
What is 5G?



5G vs 4G



5G mmWave Technology



Baseline 2 GHz:
50 MHz, 4x4 MIMO

Upper cmWave 28 GHz:
500 MHz, 64x4 SISO

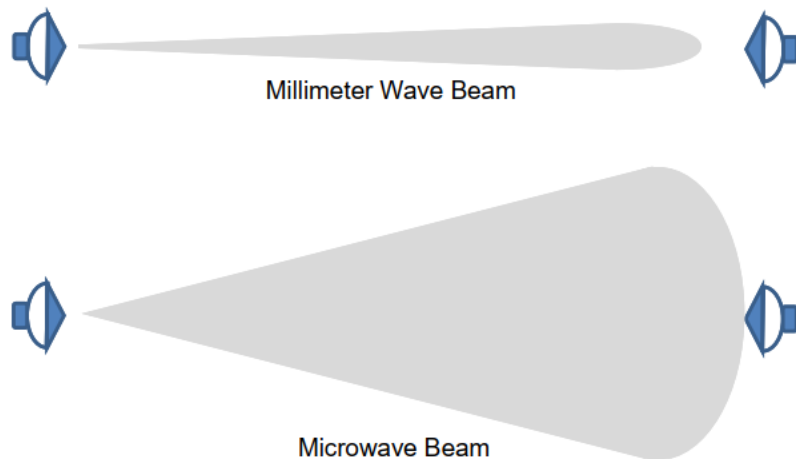
mmWave 72 GHz:
2 GHz, 400x25 SISO

MmWave can provide high peak, average, and outage rates (if dense) *

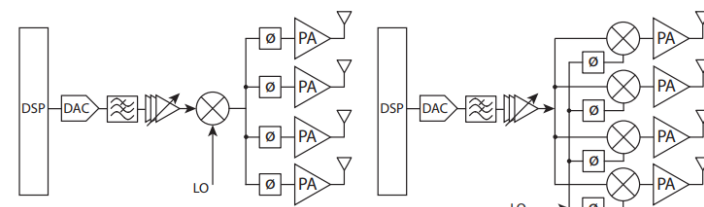
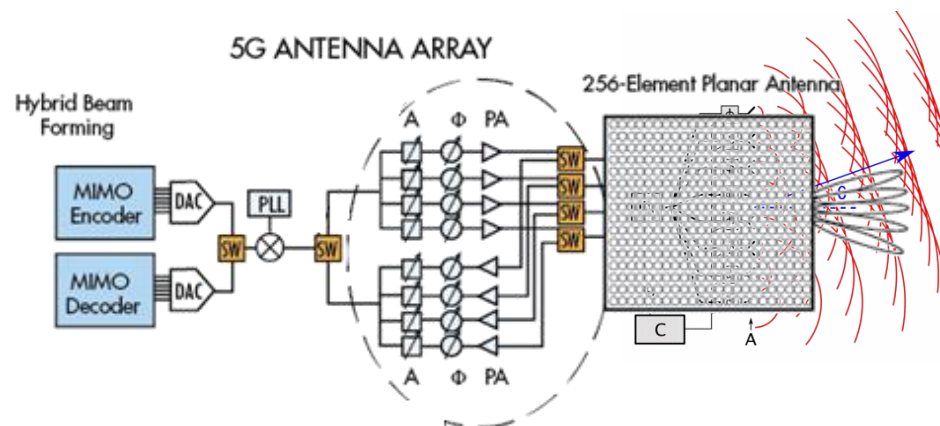
* T. Bai and R. W. Heath Jr., "Coverage and rate analysis for millimeter wave cellular networks", IEEE Trans. Wireless Commun., Feb. 2015.

** T. Bai, A. Alkhateeb, and R. W. Heath, Jr., "Coverage and Capacity of Millimeter Wave Cellular Networks," IEEE Communications Magazine, Sept. 2014.

5G mmWave Beamforming Technology

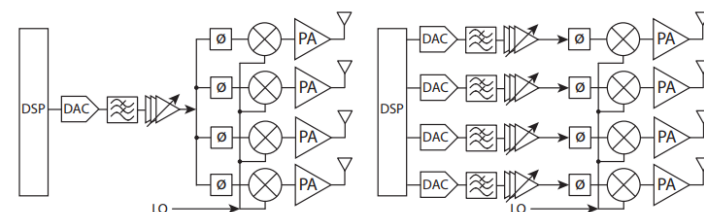


Millimeter-wave need narrow beam due to high path loss



(a) RF Phase Shifting

(b) LO Phase Shifting

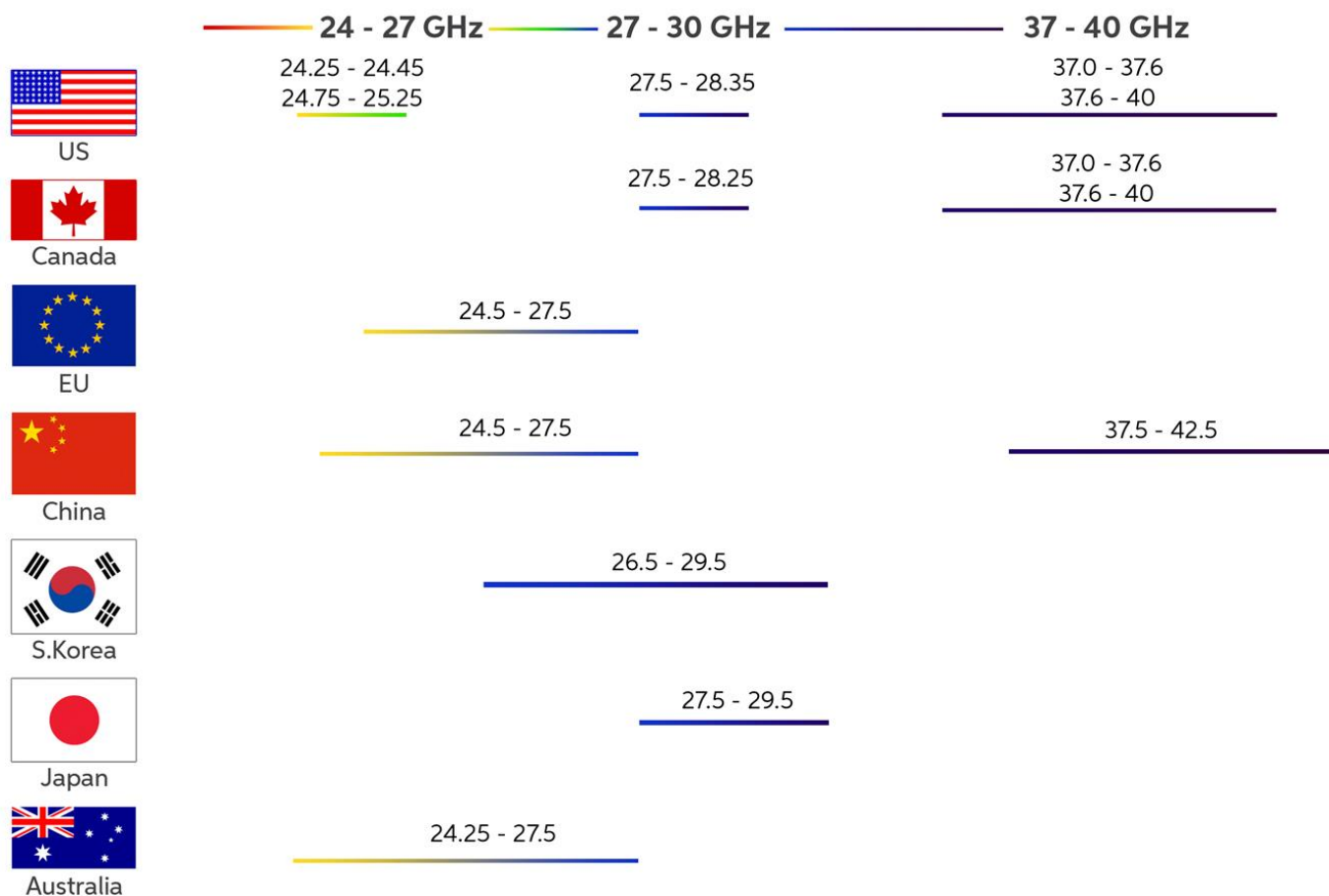


(c) Analog Baseband Phase Shifting

(d) Digital Baseband Phase Shifting

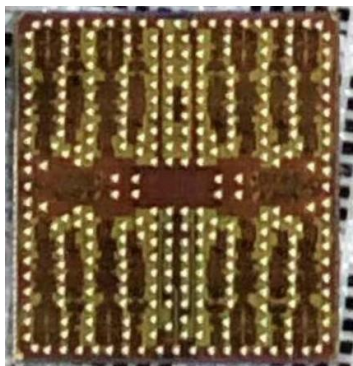
5G mmW Spectrum

Global Snapshot of mmW 5G Spectrum



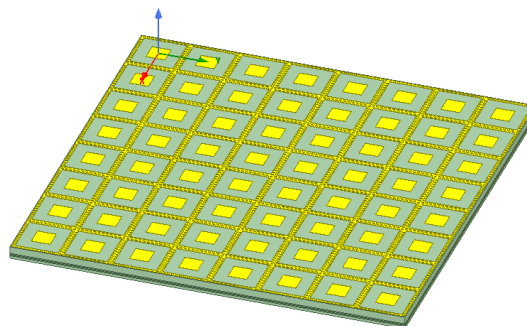
Speed Towards 5G

- Develop the CMOS Transceiver with Extra-wideband
- Design antenna phased array
- Front End Module (FEM) / Active Antenna Unit (AAU) integrated T/R RFIC with ant. array by advanced package (HDI-PCB, Flipchip, InFO-WLP, etc.)



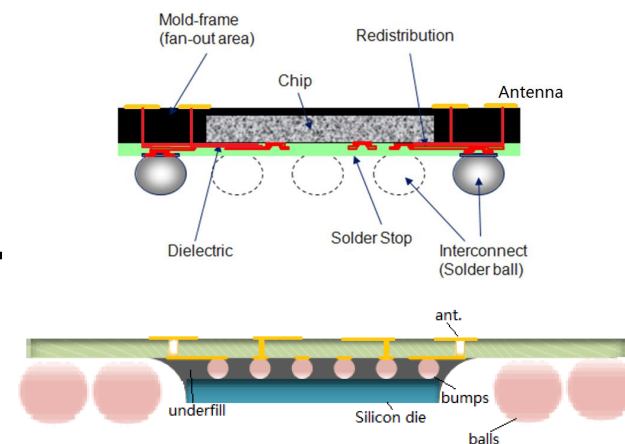
Extra-wideband RFIC

+



Phased array design

+

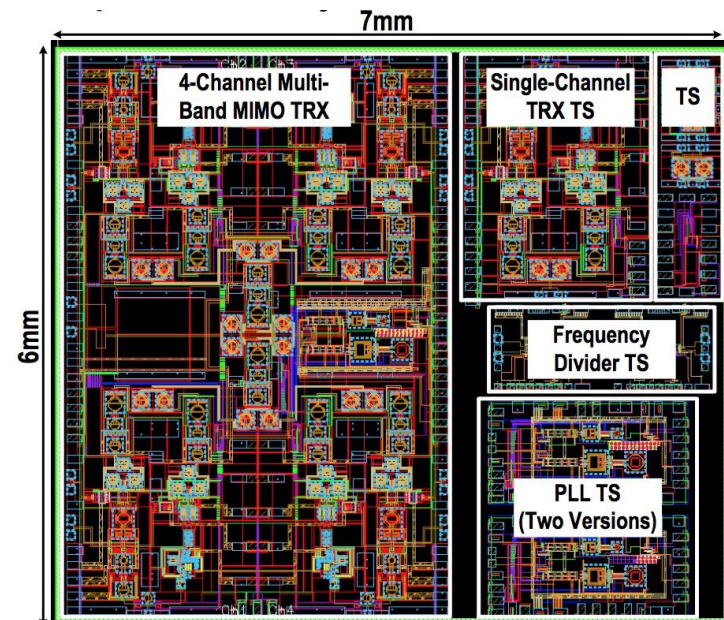


Advanced Package Tech.

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Broadband RIFC Chip Design

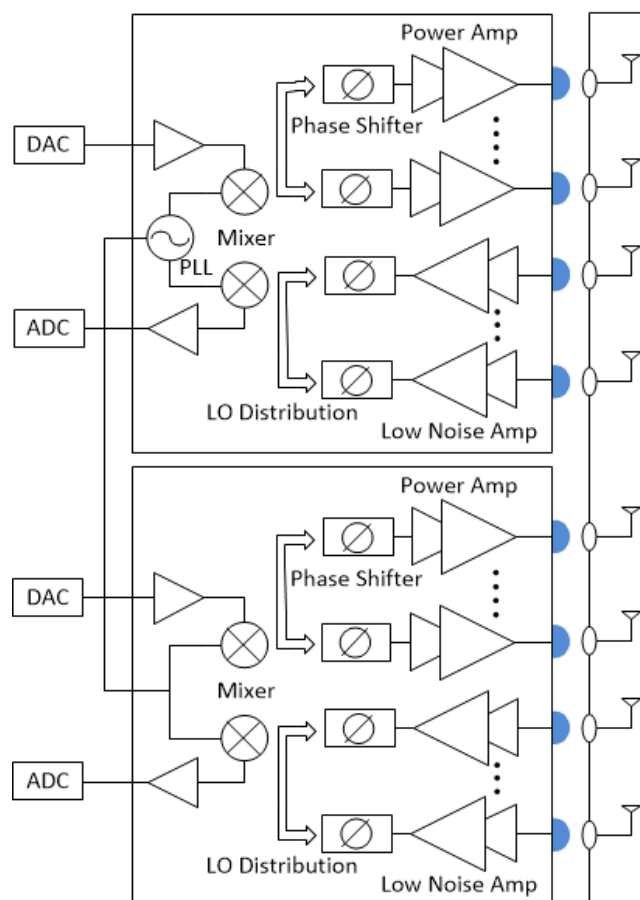
- Cover multiple 5G bands: 24G, 28G, 37G, 39G, 43G
- Image rejection T/RX
- Individual T/RX I/O for 4 channels
- 45nm CMOS SOI by Global Foundries



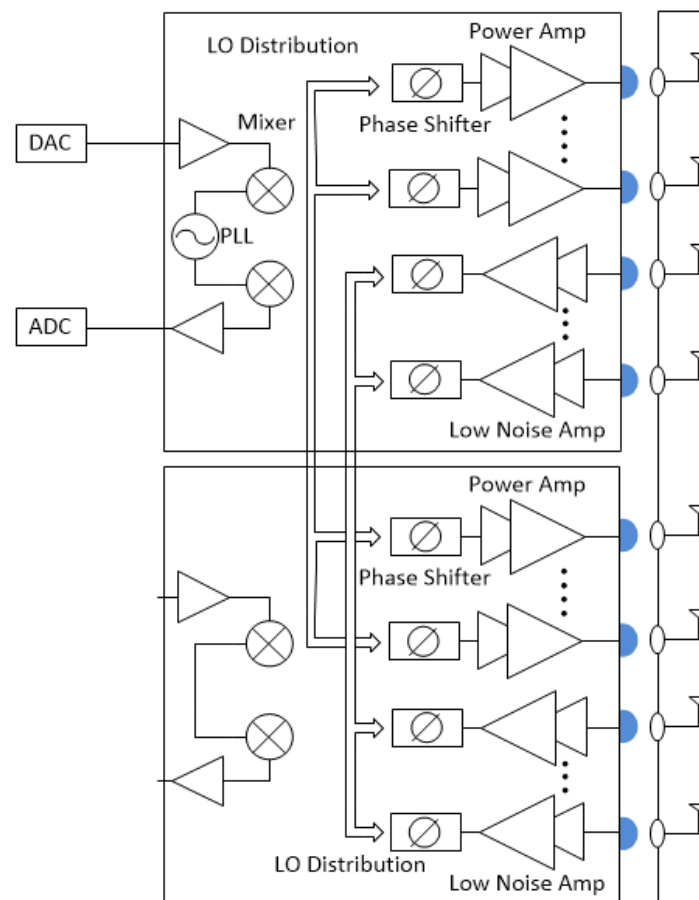
	Tx chain (TR-SWT PA Mixer IFVGA)					Rx chain (TR-SWT LNA Mixer IFVGA)			
Freq. (GHz)	24.5GHz	28GHz	38GHz	42.5GHz	Freq. (GHz)	24.5GHz	28GHz	38GHz	42.5GHz
Max Gain (dB)	29dB	28dB	21dB	21dB	Max Gain (dB)	35dB	39dB	34dB	31dB
Pout _{1dB} (dBm)	16dBm	17dBm	16dBm	13dBm	Noise figure (dB)	4dBd	4.4dB	5dB	6dB
Entire TX efficiency at Pout _{1dB} (%)	9%	10%	7.7%	5.8%	IRR (dB)	32dB	28dB	23dB	23dB
AM-PM (degree)	10	9	7	8	Pin _{1dB}	-30~-33dBm			



Scalability to Massive MIMO & Phased Array



MIMO

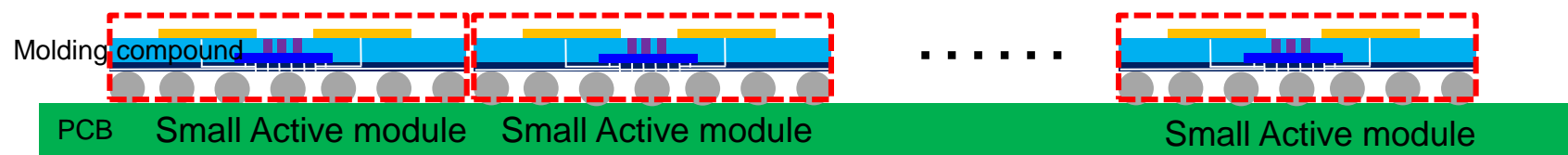
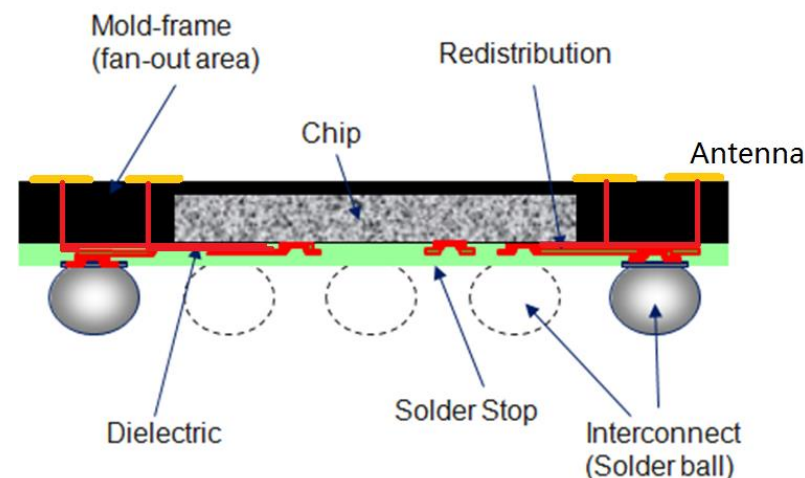
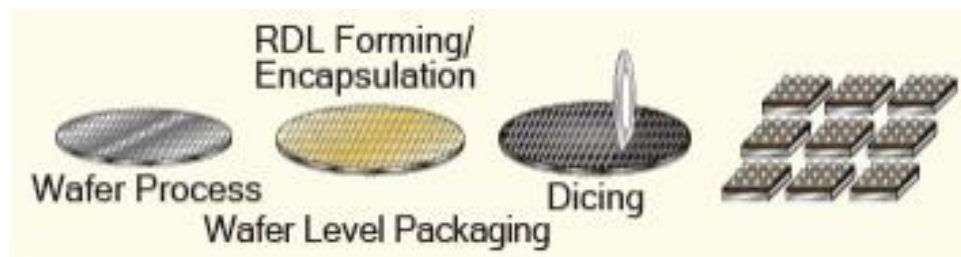


Phase Array

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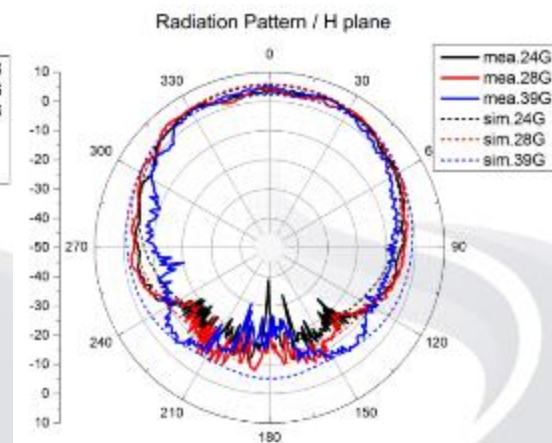
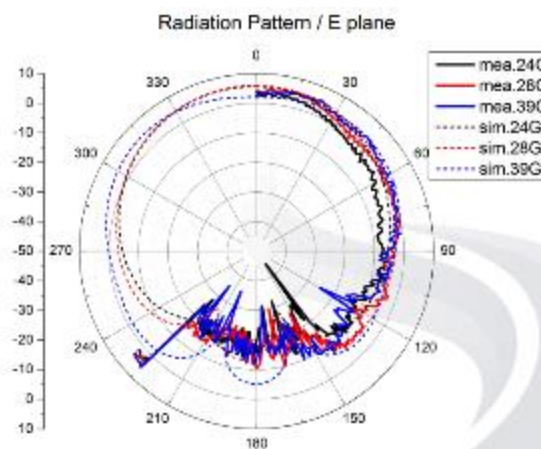
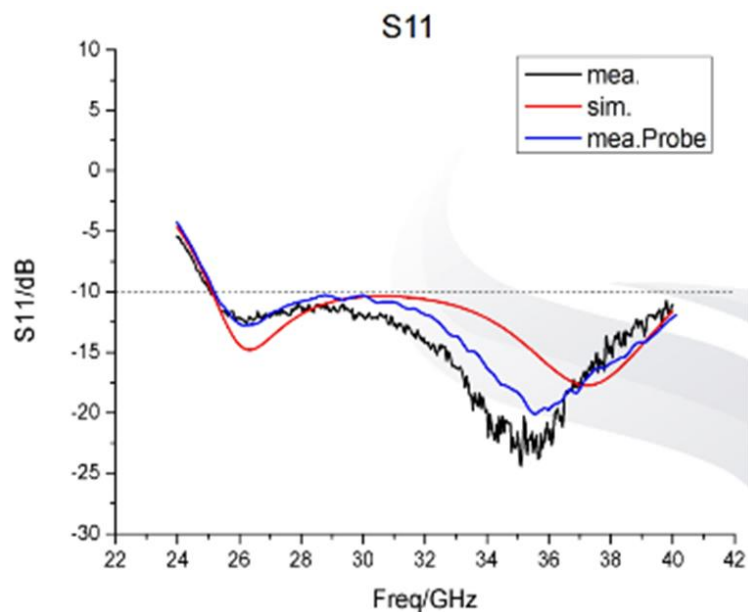
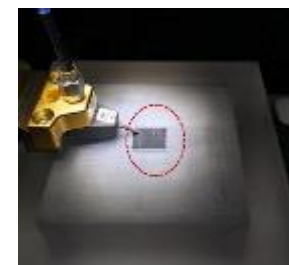
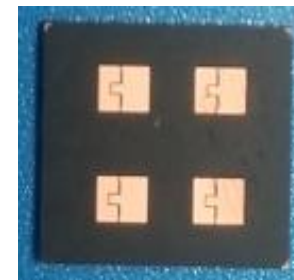
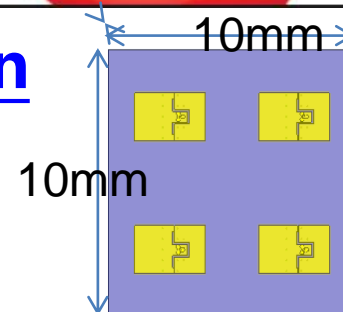
InFO WLCSP Description

- Integrated Fan-Out Wafer Level Chip Scale Packing module with ant. and RFIC
- Small module consists of 1 or 2 RFICs & several ant.s, flexible in large scale array
- Large module consists of whole ant. array & RFICs, highly integrated



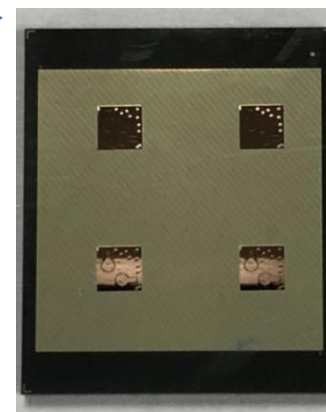
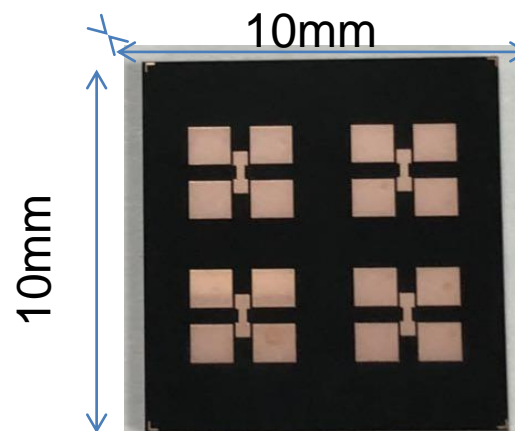
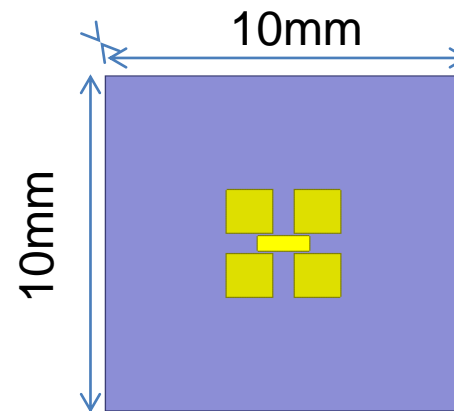
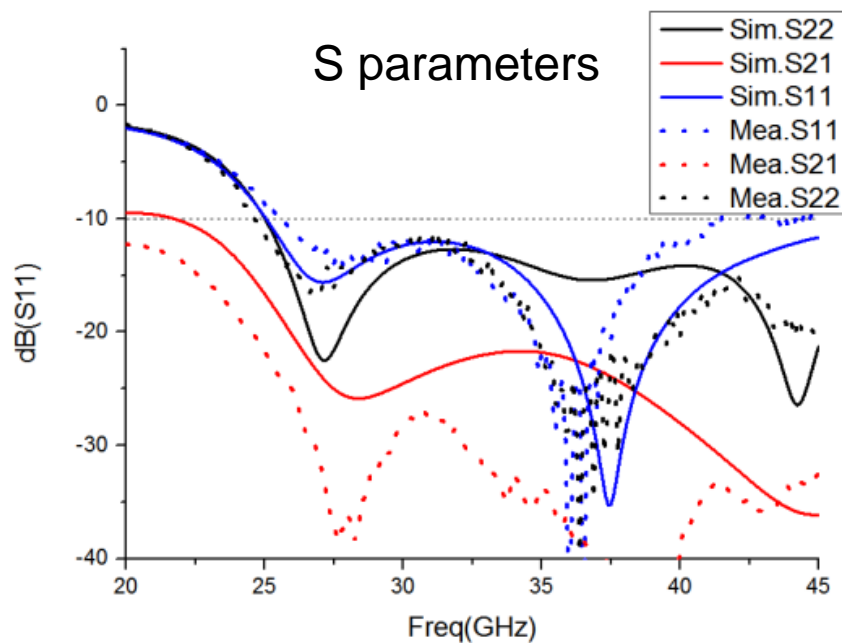
InFO WLCSP Single-pol Ant. Design

- Package antenna with Wideband Patch Ant.
- Substrate using molding compound material
- Single polarization design with extra-wideband
- BW from 24.25GHz to 43GHz
- Measurement agree well with simulation



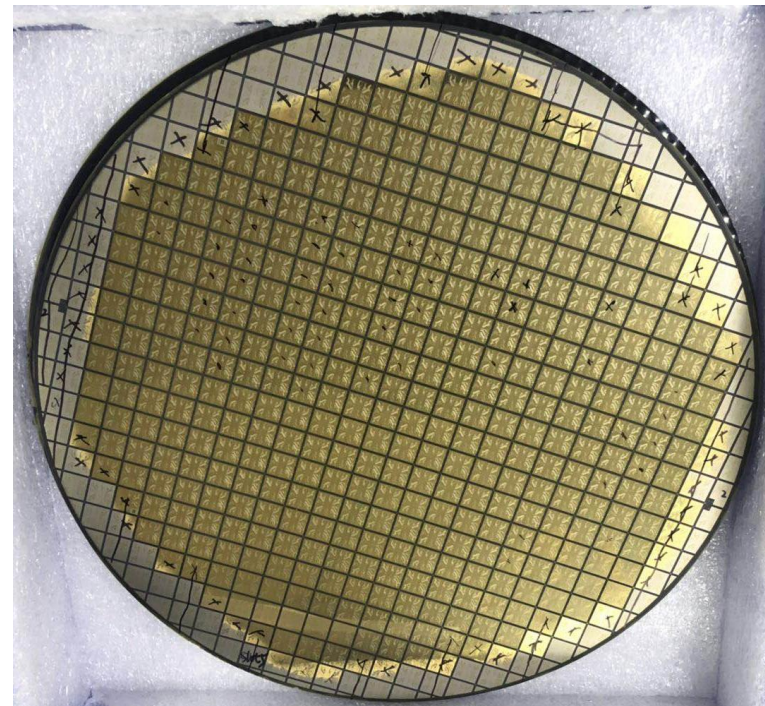
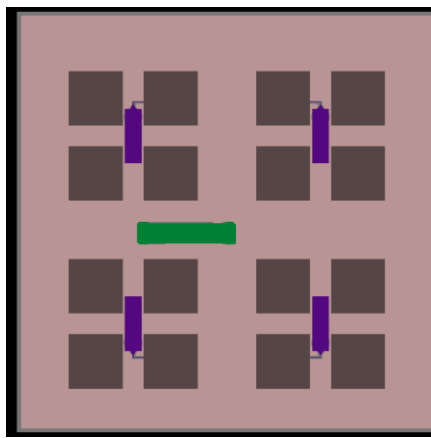
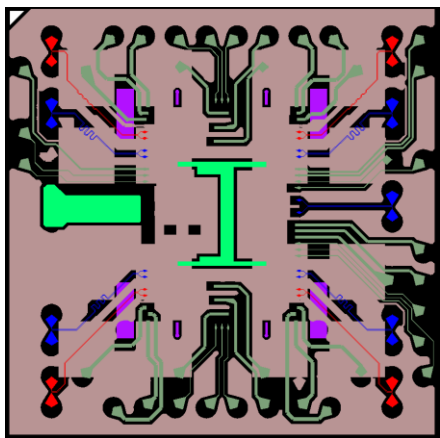
InFO WLCSP Dual-pol Ant. Design

- Wideband Patch Ant. With Dual-polarization
- Substrate using molding compound material
- Extra BW from 25GHz to 43GHz
- Measurement agree well with simulation



InFO WLCSP FEM Design

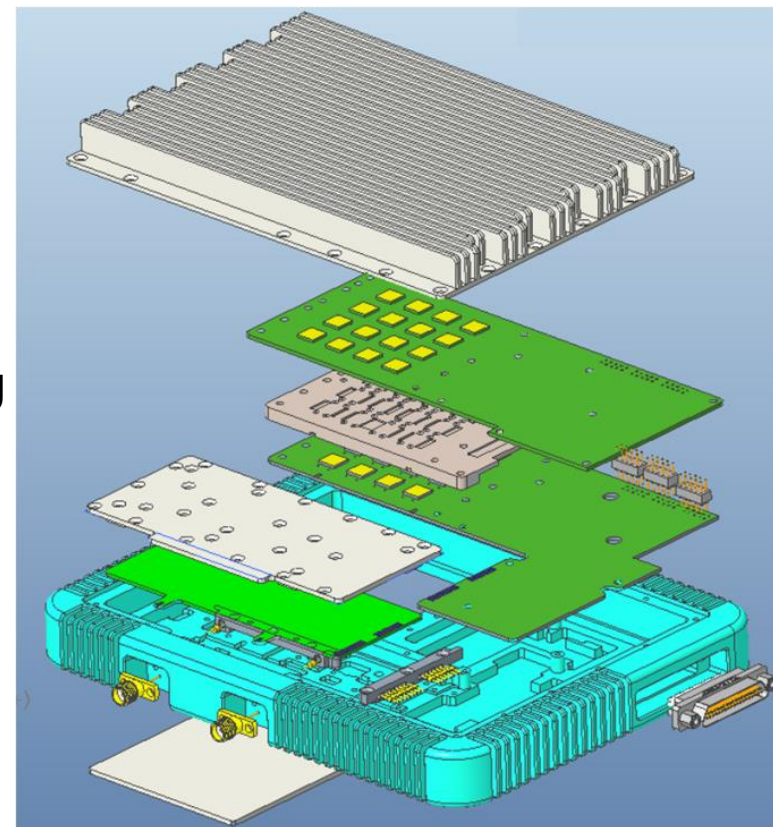
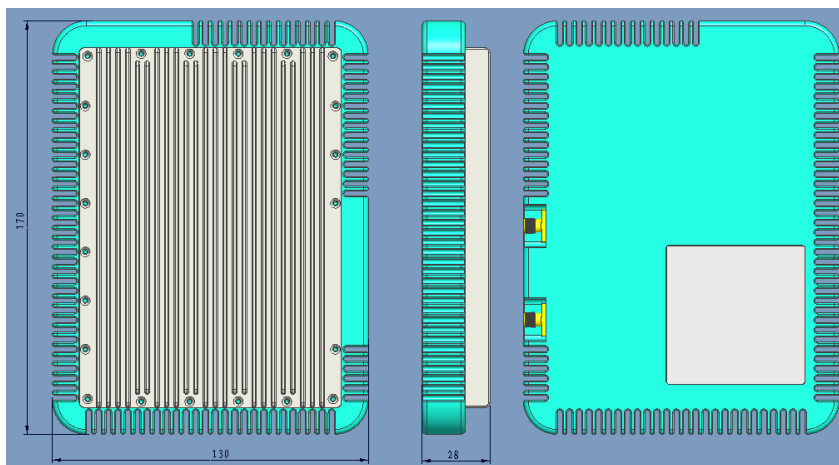
- Ant. module size of $10*10*1\text{mm}$
- Four layers include ant. & RFIC connect
- Molding compound support & PI for RDL layer



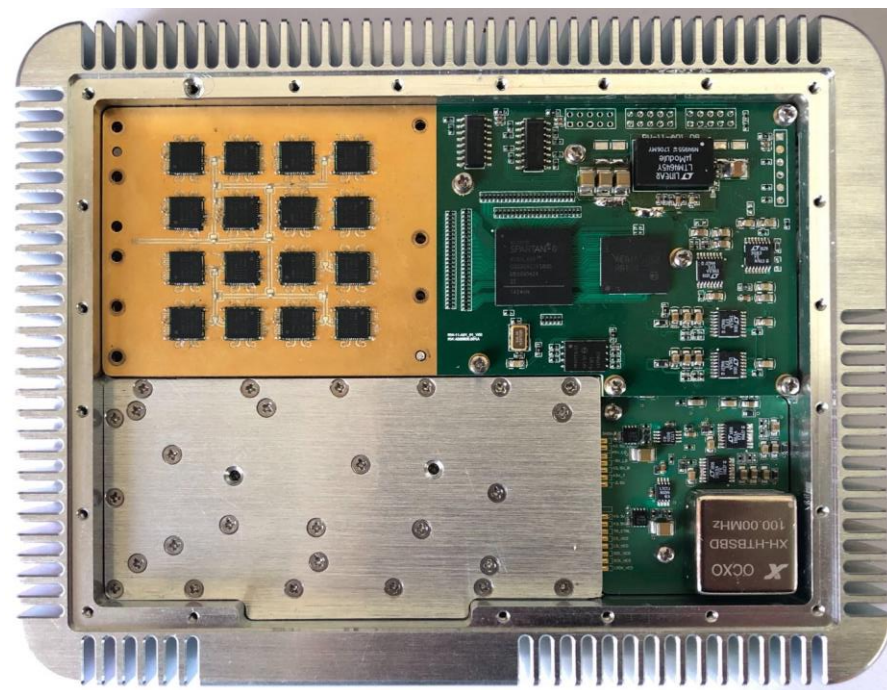
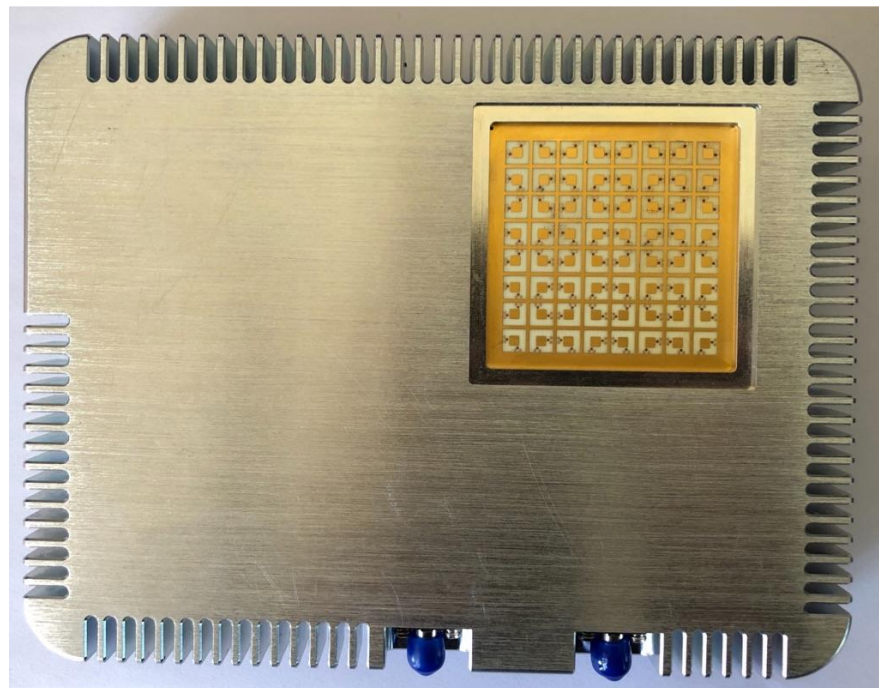
12 inch Plate Manufactured by SJSemi

Phased Array Module Design

- Ant. array designed with dual-polarization
- RF freq from 26.5 to 29.5GHz @ VSWR<1.5
- IF freq from 9 to 11GHz
- Phased array module integrate Ant. with RFIC
- 8*8 beamforming scan angle from -60 to 60deg
- ERIP reaches 50dBmi
- Total size : 170mm*130mm*28mm

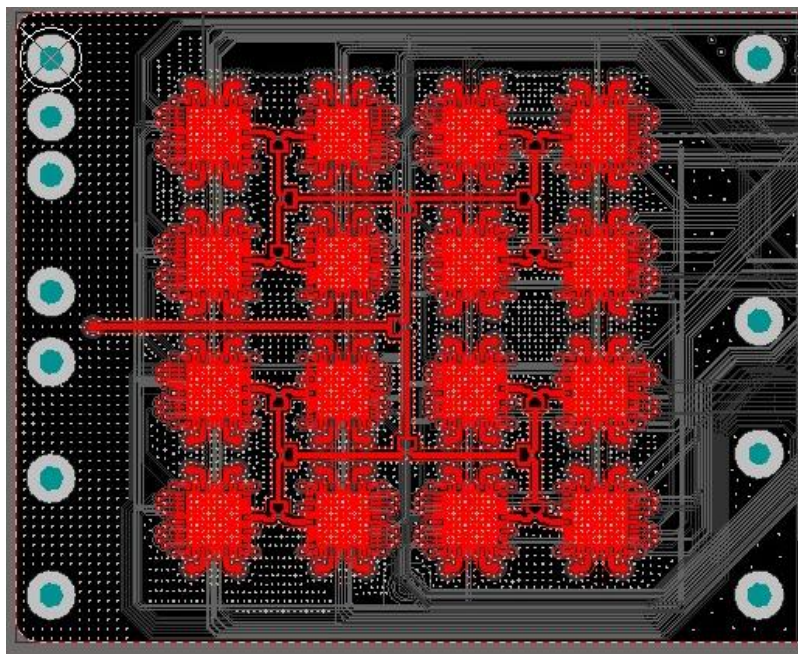


Structure Details

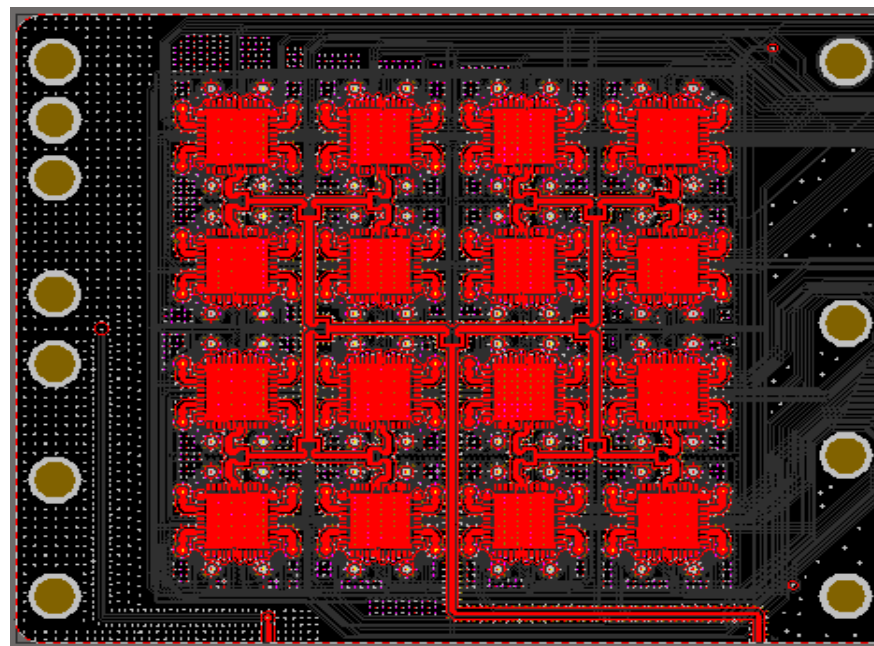


Polarization RFIC Layout

Horizontal polarization

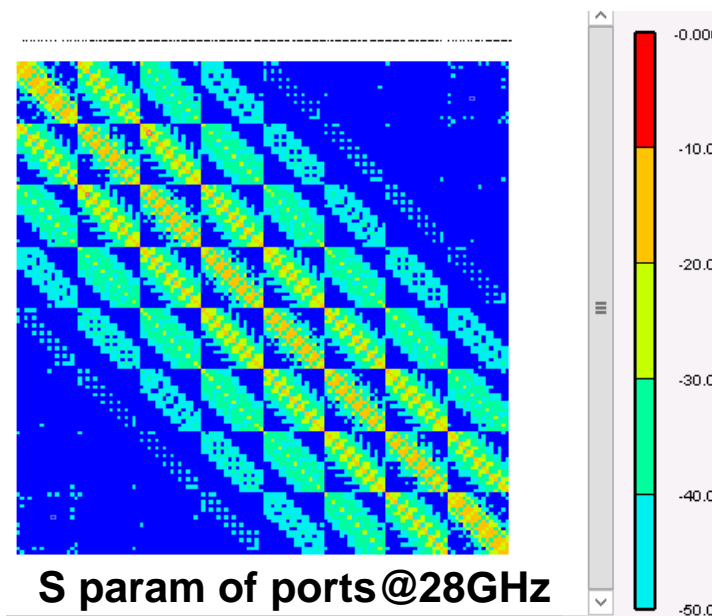
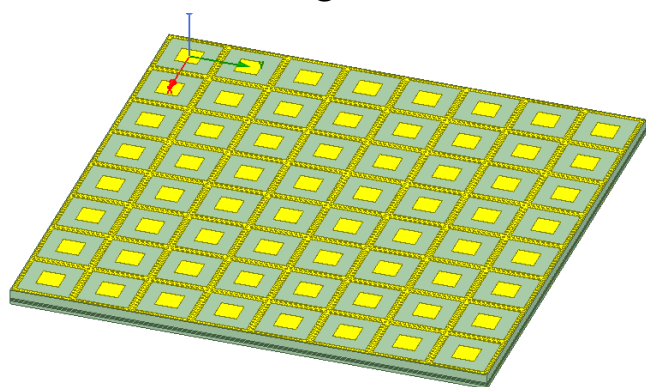


Vertical polarization



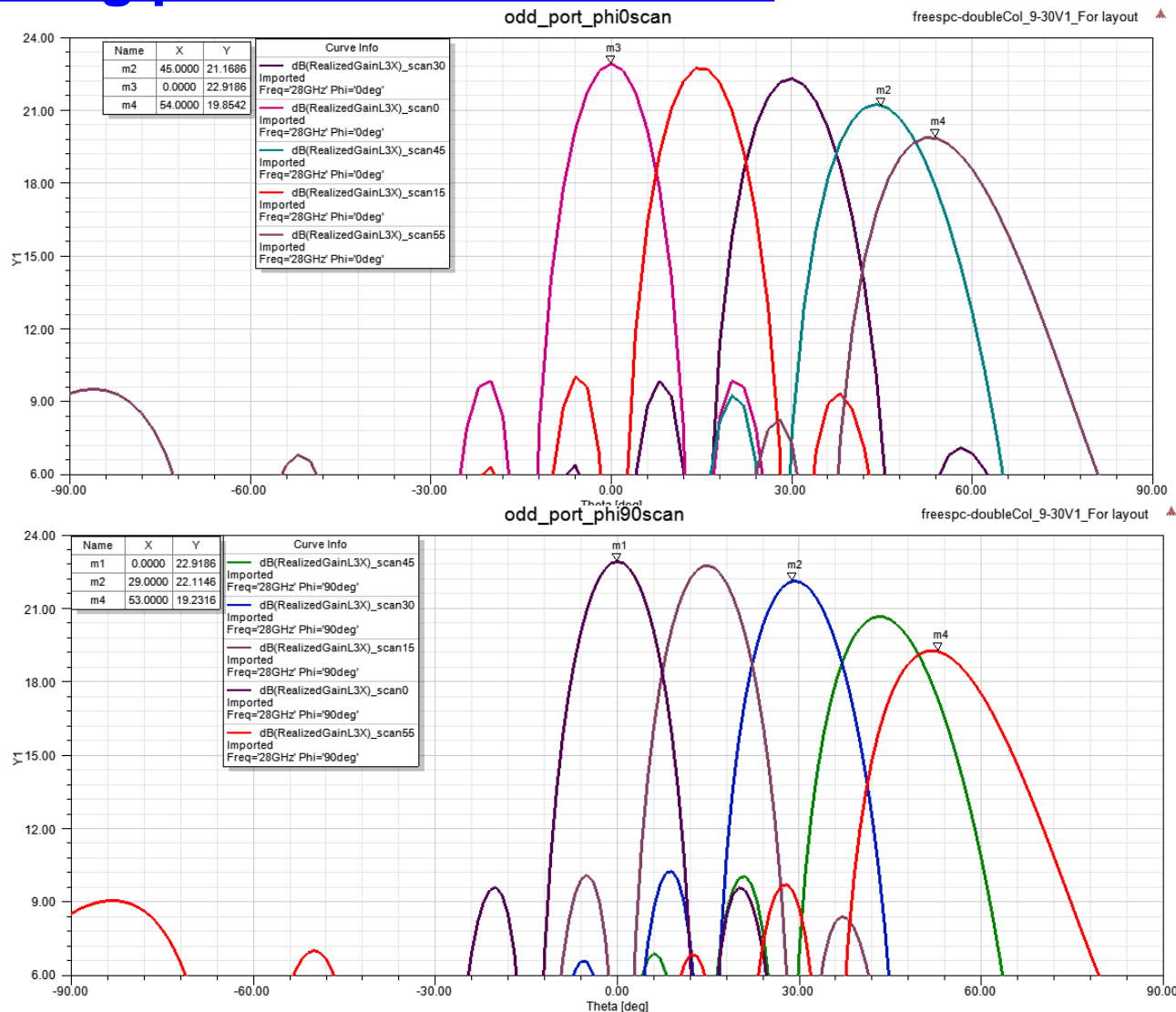
Ant. Array Details

- 8*8 ant. Array with dual-polarization
- 44mm*44mm*1.43mm
- BW covering from 26.5GHz to 29.5GHz

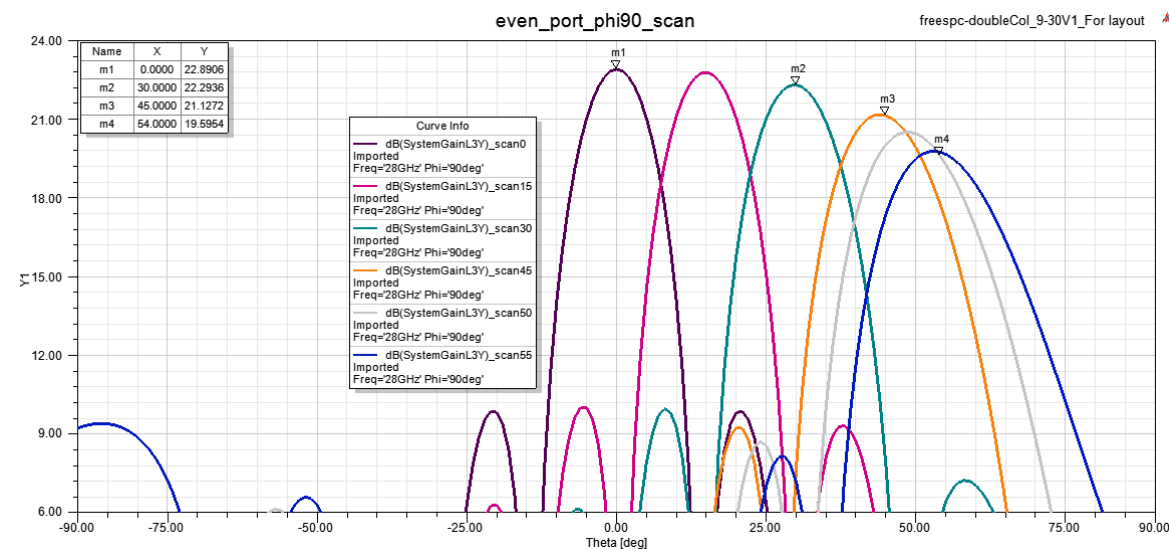
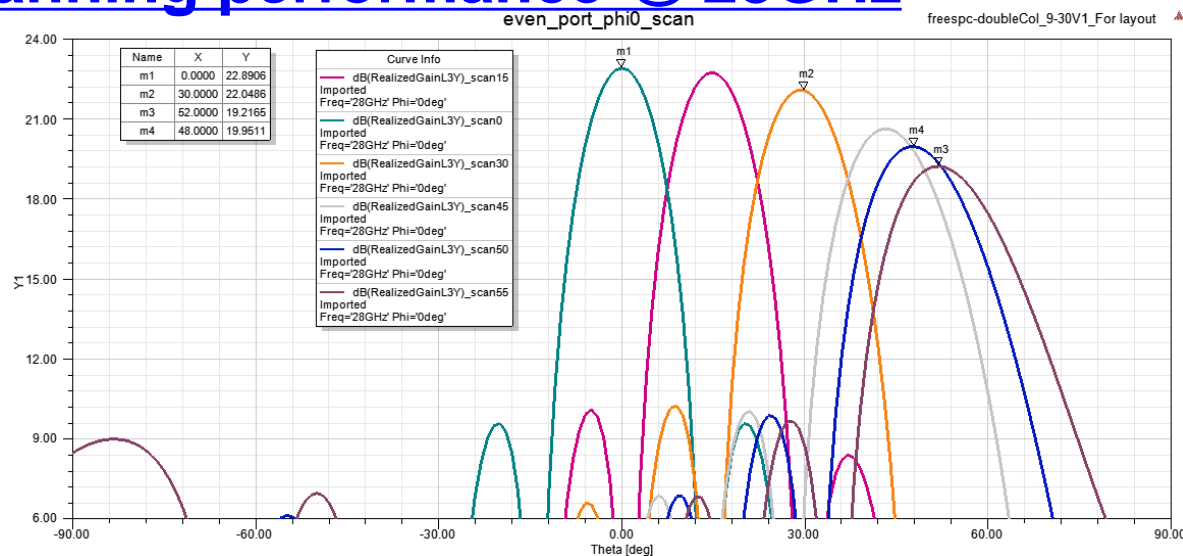


f (GHz)	S1,2 (dB)	S1,3 (dB)	S1,4 (dB)	S57,58 (dB)	S55,57 (dB)	S56,57 (dB)
26.5	-32.7	-16.1	-32	-34.3	-15.5	-52.6
28	-35.6	-17.9	-33.2	-38.3	-16.5	-69.6
29.5	-42.3	-19.7	-33.8	-42.2	-18.4	-73.7

V-Pol Scanning performance @ 28GHz

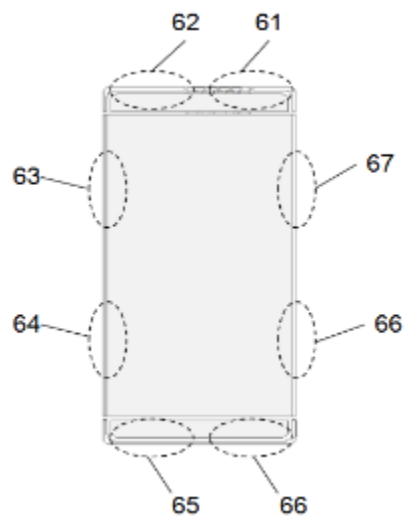
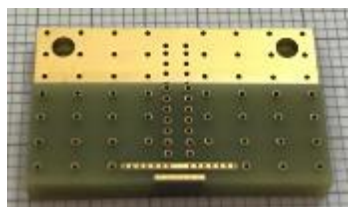


H-Pol Scanning performance @ 28GHz

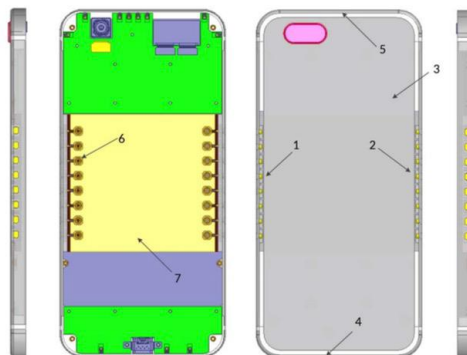


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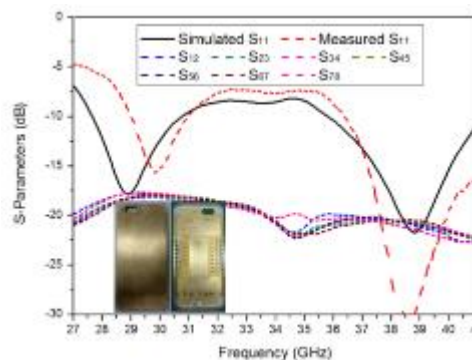
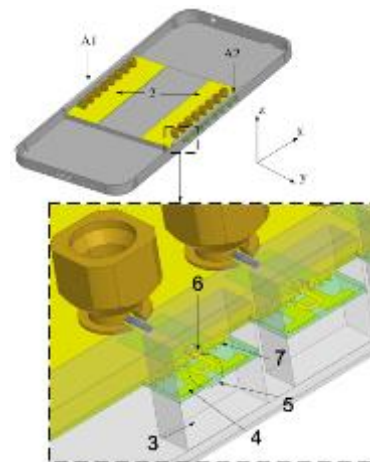
mmWave Mobile Terminals Ant. Design



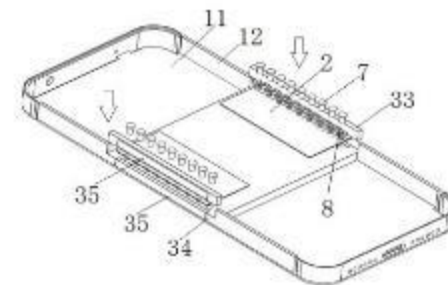
End-fire ME dipole
Patented



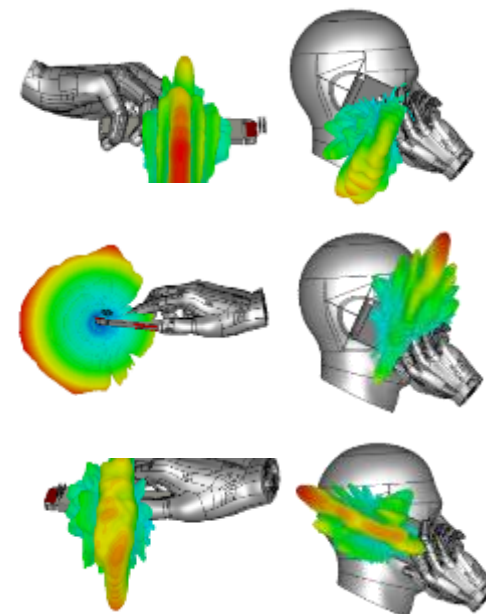
Cavity back slot
Patented



Dual-band slot
Patented

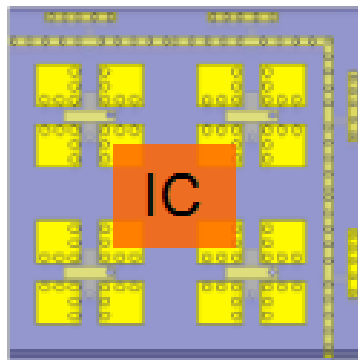
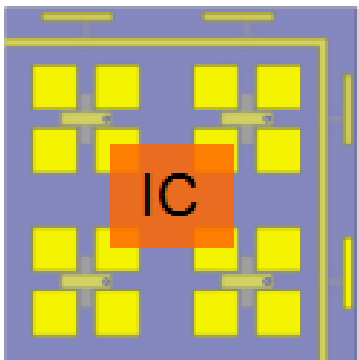
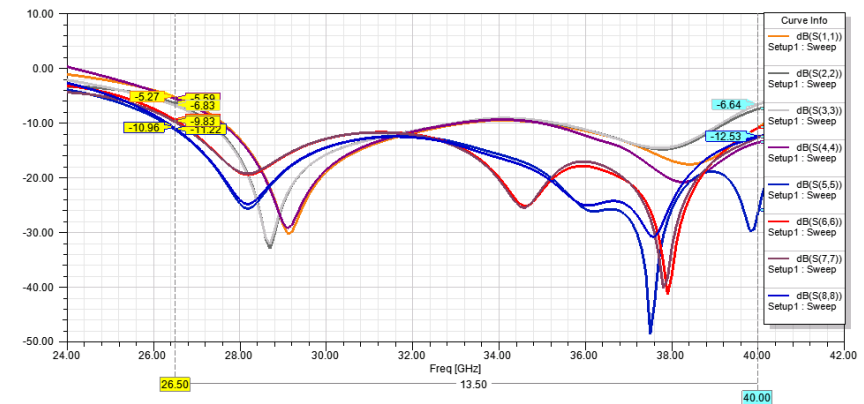


Broadband dipole
Patented

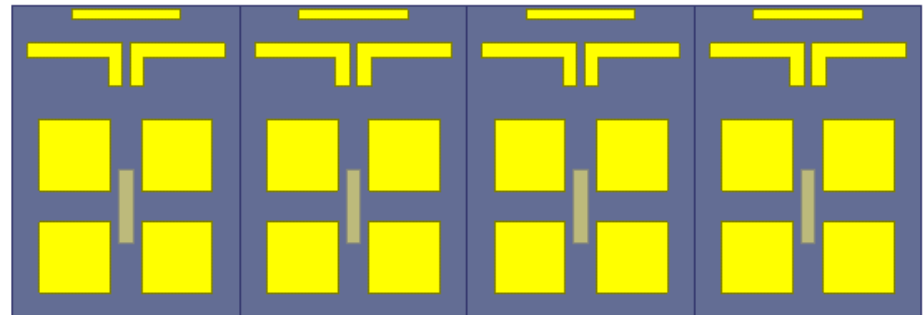


mmWave Mobile Terminals FEM Design

- Broadside ant. array by ME dipoles element
- Endfire ant.array designed by dipoles element
- RFIC with 4 channels @ 24GHz to 43GHz



AiP module size: 10*10*1mm



General dimension: 19.2mm(L)x6.6mm(W)x1.0mm(H)



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Thanks